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"A model for visual attention"

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Research has been undertaken in three areas concerning human visual attention: the AGM model for attention shifting, iconic memory, and visual imagery.

1. Shifting visual attention.

We employed the attention-shift RSVP (rapid serial visual presentation) paradigm to study attention shifts. In this method, an observer sees two streams of alphanumeric characters which appear, one after another (i.e., serially), side by side to the same two locations on a display monitor. The characters are presented rapidly (up to 13 characters/ sec), but not so rapidly that they blur together. The task requires the observer to monitor the stream at the left for a target character. Having detected the target, he must shift attention to the stream at the right. The observer must then report the first four numerals that he can from the numeral stream. In earlier work, it was found that observers reported numerals from the numeral stream in non-veridical orders. Typically, numerals that were presented 400 msec after the target were reported as seen first. Other numerals, presented both before and after this, were typically reported as being seen later in the stream (the order was 'folded'). Since the numerals were presented too fast to be individually named, and because subjects reported actually seeing the numerals in an order different from the presentation order (which they knew from feedback after the trial), we (Reeves & Sperling, 1986) concluded that this was a result of shifting attention on short-term visual (not verbal) memory (VSTM).

The purpose of the present work was to further develop and test an attention gating model (AGM) for this effect. The essential idea (Reeves & Sperling, 1986) is that attention operates to gate items into VSTM. A curve was derived which describes a rapid opening and slow closing of the attention gate. The order of items in VSTM (and thus in the observer's reports) is determined by the presentation times of the items, the amount of attention they receive while being gated into memory, and a weighted integral of the latter quantity. The model described the original data set, in which numeral rates and targets were varied, to a high degree of accuracy with few parameters.

A prediction of the model is that the attention shift should follow the same time course, controlled by the gating signal, no matter what load on memory is demanded by the numeral stream to which attention is being shifted. To test this, I required the observer to recall either 2, or 4, or 6 numerals on each trial. This work was begun in the previous grant and finished in this one. The same model parameters derived, say, from the recall-4 trials, described the data from the recall-2 and recall-6 trials, supporting the model (Reeves, in prep).

Another prediction is that the time of gate-opening into short-term memory should be independent of the spatial positions of the streams. That is, attention operates to turn on a gate at a specific (known)

position, not to 'move' attention, in spot-light fashion, from one stream to the other. Earlier work at NYU (with Sperling and Weichselgartner) supported this prediction, but eye movements were not measured. I have confirmed the main findings with an ISCAN eye-tracking system, bought by this grant (Reeves, in prep).

A similar prediction is that the effect of the attention shift (folding of order) should not depend on the presence or absence of saccadic eye-movements. This prediction, which again follows from the assumption of gate-opening, is in opposition to a plausible alternative: that folding arises because of the un-naturalness of moving attention without moving the eyes. In the studying this issue, I have found it easy to move attention with the eyes, or when the eyes are still, and in both cases folding occurs. However, moving the attention from the letter stream to the numeral stream while simultaneously moving the eye in the opposite direction appears to be very difficult. After 30 hours of practice, it is possible to move in opposite directions on a minority of the trials (the exact fraction depends on the strictness of the criterion for simultaneity of the eye-movement and the attention shift). Hence, one cannot conclude that saccadic eye movements and attention shifts are totally independent (Reeves, in prep.).

2. Attention and iconic memory

We (Charles Tijus, a Post-Doc supported on the grant, and I) have begun a line of experiments concerning the influence of attention on visual short-term memory in the spatial domain. In one series of experiments, we found that the presence of depth improved report from VSTM. We used the familiar Sperling (1960) partial report paradigm with a 3 row by 4 letter display. The partial report cue specifies the row: because the depth condition is blocked, the subject knows which depth plane corresponds to which row. Accuracy for partial report is higher when the rows are placed in different depth planes than when they are all at the same depth. This is true for depth defined by stereo or by perspective. Specifically, position errors within rows are the same for depthful and flat displays, but adding depth almost eliminates between-row interchanges. We suggest that the depth cue facilitates paying attention to the cued row (Reeves & Tijus, in prep.).

We also asked subjects to decide whether a cue and a target were the same or different; on some trials, a distractor (an outline square) was also positioned randomly on the display. The distractor lowered accuracy when it was in the same depth plane, but had little effect when it was portrayed behind or in front of the cue-target depth plane. This was true for a variety of cue-target distances (from one to 12 deg). Again, we suggest that depth can facilitate attentional selectivity; in this case, by helping the subject ignore an irrelevant distractor (Tijus & Reeves, in prep.).

In the course of this work, we discovered that the standard formula for the standard error of d' (Gourevitch & Galanter), used to provide statistical tests of whether two d' 's differ or not, is usually in error with N less than 100, often by 30% or more. We Monte-Carloed a number of cases of interest to vision scientists, in which the variance of the $S+N$ distribution exceeds that of the N distribution by various fixed factors, varying N from 10 to 1000, and Phit and Pfa, and came up with an empirical formula which predicts the actually obtained variances within 5% (Reeves & Tijus, 1989).

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In a further line of work, we (Reeves & Tijus, 1989) found that flashing a homogeneous white field could disrupt VSTM. Subjects continuously viewed a white field, on which a 12-letter display appeared; the letters were drawn in black. Subjects had to report which of N (1, 4, or 6) letters in the display suddenly disappeared. They were normally quite good at this (we estimate 9 letters available from a 12 letter display); but if the white screen was flashed for 16 msec, just 16 msec before the disappearance of the target letters, availability fell to 3 letters. Flashing 32 msec before or after had very little effect.

Our result of 16 msec temporal precision disagrees with a report by Pashler (P&P, 1988), who reported that visual memory was disrupted after a 64 msec flash. However, his subjects only had to detect the presence of change (one letter in the display suddenly changed), not identify the changed letter. In the only condition in which subjects did well, an apparent motion cue (the writhing of one letter into another) could have provided the cue for change. In the other conditions in which performance was poor, due to a white flash or a mask, such a motion cue may have been disrupted. Moreover, the residual performance was estimated at 4 letters available, typical full-report performance -- not surprising, since no partial report cue was ever given! So Pashler's data can be accounted for by assuming full report, augmented by a motion cue where this was present; nothing need be inferred about VSTM at all.

3. Visual attention and visual imagery.

We have completed a series of experiments on the effects of visual imagery and visual attention on visual acuity. Distracting attention, and having a visual image, can both reduce acuity; they do so non-interactively in some conditions (when attention is split between two possible target locations), and interactively in others (when attention is divided between a single target location and a second task of monitoring a winking LED for an occasional change in wink rate). These results are independent of location (foveal versus peripheral targets /distracters) and provide a puzzle for possible future consideration (Lemley & Reeves, 1989).

PAPERS

Reeves A. (1989) Further tests of a model of short-term visual memory (in prep.).

Lemley C.R. and Reeves A. (1989) Visual imagery and visual attention. Submitted.

Tijus C & Reeves A (1989) How to destroy the icon. Submitted.

Tijus C & Reeves A. Depth effects on iconic memory. (In prep.)

Reeves A & Tijus C. Attentional effects with stereoscopic depth. (In prep.)

Reeves A & Tijus C. (1989) Estimating d's and its variance. Under review for Perception and Psychophysics.

PRESENTATIONS

Reeves A & Tijus C. (1988) Iconic memory and depth. Given to the Psychonomic Soc., 29 th. annual meeting, Chicago Ill.